# BIOLOGICAL SURVEYS OF FIVE SOUTHERN ARTIFICIAL REEFS: OCEANSIDE #1 , OCEANSIDE #2, CARLSBAD, PACIFIC BEACH, and MISSION BAY

*by* **Dennis Bedford, Jerry Kashiwada** *and* **Greg Walls**

Marine Resources Division
Administrative Report 95-6
1995

Marine Resources Division Administrative Report Series

These internal documents provide a quick way to disseminate diverse material such as preliminary research results, fishery status reports, and reports to contracting agencies, the Legislature, the Fish and Game Commission, and Department Headquarters. The series is authored by Department personnel and is not subject to peer review.

Instructions on report preparation can be obtained from the Administrative Report editors:

Northern California - Diana Watters, Menlo Park
Southern California - Greg walls, Long Beach

**Acknowledgments**

We wish to thank Bill Maxwell, Fish and Game/Sport Fish Restoration Act coordinator, for his support of the program, and to the Dingell-Johnson Federal Sport Fish Restoration Act which provided the funding necessary to obtain the information needed to improve sport fish habitat through the construction of artificial reefs.

We also wish to thank Dave Parker for editing the final report.

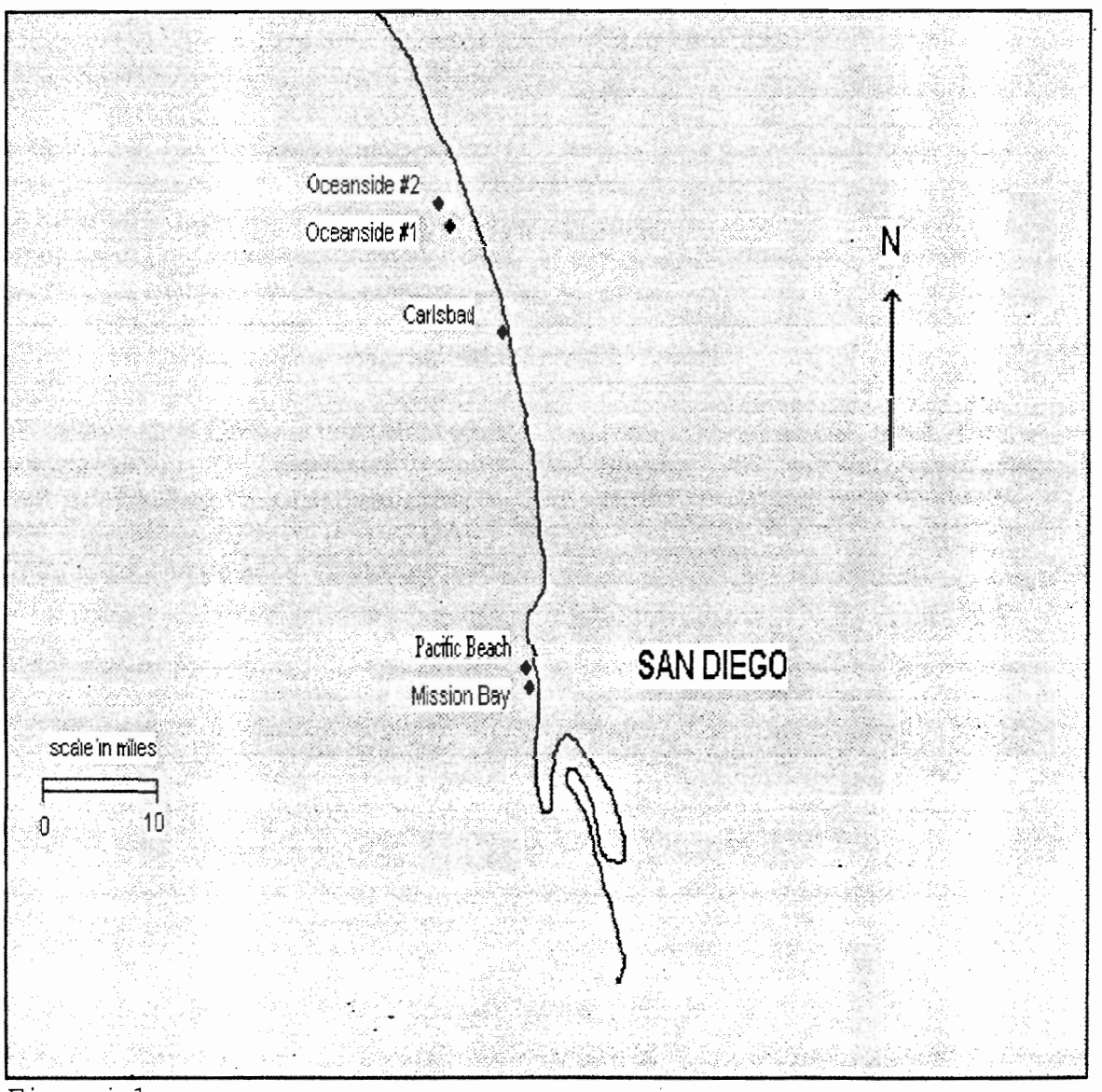



Figure 1

## Introduction

This report details the development of the biological communities on 5 artificial reefs off southern California (Figure 1). Oceanside #1 (OAR1), the oldest reef of this group, was constructed of 2,000 tons of quarry rock in 1964 and augmented with concrete dock floats in 1987. Oceanside #2 (OAR2) and Pacific Beach Artificial Reef (PBAR) were each constructed of 10,000 tons of quarry rock in 1987. The **Ruby E**, an 165 foot U.S. Coast Guard rumrunner blockade vessel built in 1934, was placed at the Mission Bay Artificial Reef (MBAR) site in 1989. Carlsbad Artificial Reef (CAR) was built in 1991 of 10,000 tons of quarry rock.

OAR1 and MBAR were created primarily to enhance fishing opportunities for recreational anglers. OAR1 consists of eight quarry rock modules, but there have been few studies of this reef and it is not certain whether any of the modules have been covered by sediment. OAR2, PBAR, and CAR are replication reefs which were designed by researchers to study the effects of environmental and structural variables on reef productivity *in situ*. OAR2 and PBAR are composed of 12 module pairs arranged along three depth strata with varying height and boulder size (Table 1 & Figure 2) while CAR has 12 single modules similarly arrayed. Their purpose was to (1) provide shelter, forage, nesting, and nursery areas for fishes and invertebrates; (2) offer rocky substrate for the attachment and growth of marine plants, particularly giant kelp (*Macrocystis* sp.); and perhaps most importantly, (3) act as "experimental" reefs for investigating the effect of reef location, depth, relief, and rock size on the successional development of the associated biotic communities.

During the late fall of 1994 all five reefs were surveyed by Department divers to assess how closely their biological communities have progressed towards a stable "equilibrium" community. Due to the young age of the reefs (except for OAR1) and the rapid successional change which occurs in the associated biotic communities of new reefs (Carlisle *et al.* 1964; Turner *et al.* 1969; Carter *et al.* 1985; Matthews 1985; Solonsky 1985; Ambrose and Swarbrick 1989; Anderson *et al.* 1989; Hueckel and Buckley 1989; and Wilson *et al.* 1990), only qualitative surveys were conducted.

## Methods

During October, November, and December of 1994, Nearshore Sport Fish Habitat Enhancement Program (NSHEP) biologist-divers surveyed all five reefs to evaluate the assemblage of fishes, macroinvertebrates, turf communities (small sessile invertebrates and plants), and macroalgae on selected modules at each depth contour. Modules were located by using Geographic Positioning System (GPS), side-scanning sonar, and echosound. The small size of the modules coupled with favorable visibility, allowed extensive qualitative observations of the biotic communities to be made.

Relative abundances of fishes were estimated while swimming over and around a module several times. These estimates were placed into four categories: abundant (>50 individuals), common (11-50 individuals), occasional (2-11 individuals), and one (1 individual). Fish size was estimated using three categories: adult (A), juvenile (J), and young-of-year (Y).

A distinction is made between both invertebrates and algae which are large or rare enough that individuals can be counted and those whose numbers are so great that they blanket large areas of a reef. There is no clear biological distinction between these groupings, but as a matter of convenience the former are labeled macroinvertebrates and macroalgae, while the latter are categorized as the "turf" community. This categorization greatly eases our task of estimating species abundance.

Densities of macroinvertebrates and macroalgae were estimated by counting all individuals, within one meter on either side of a transect line, run from the base of a module over the crest and down to the base on the opposite side. The counts are reported as the average number of individuals per square meter ($m^2$). In addition to actual counts, macroalgae size was estimated using three categories of height: A1 (1 in.- 1 ft.), A2 (1 ft. to the subsurface), and A3 (surface canopy).

Estimated percent cover for turf community organisms was averaged for twelve pseudo-randomly placed quarter square meter quadrats and categorized as abundant (>50% cover), common (11-50% cover), occasional (2-11% cover), or rare (≤1% cover).

Physical data collected included module depth and height and water visibility. Module depth and height were determined by averaging numerous depth gauge readings taken along the module base and crest (surface), respectively.

## Results

### Physical Data

Module "G" at OAR1 was surveyed on 23 November 1994. Visibility was 20-30 feet, module height was 5 feet, and depth was 95 feet (table 1). Modules 4A (deep), 4B (mid-depth), and 4C (shallow) at OAR2 were surveyed from 18-20 November 1994. Visibility was 10 feet at the shallow module, water depth was 48 feet, and module height was eight feet (table 1). Visibility at the mid-depth module was 20 feet, water depth was 64 feet, and module height was 9 feet. Visibility at the deep module was 15-25 feet, water depth was 72 feet, and module height was 8 feet.

Modules 37-1 (shallow), 42-1 (mid-depth), and 57-1 (deep) were surveyed at CAR on 24-25 November 1994. Visibility at the shallow module was 5-25 feet, height was 7 feet, and water depth was 43 feet. Visibility at the mid-depth module was 3-15 feet, height was 9 feet, and water depth was 46 feet. Visibility at the deep module was 10 feet, height was 9 feet, and water depth was 58 feet.

Modules 1A (deep), 2B (mid-depth), and 4C (shallow) were surveyed at PBAR on 2-6 November 1994. Visibility at the deep module was 25 feet, water depth was 76 feet, and module height was 10 feet. Visibility at the mid-depth module was 40 feet, water depth was 60 feet, and module height was 11 feet. Visibility at the shallow module was <10 feet, water depth was 47 feet, and module height was 9 feet.

One wreck was surveyed at MBAR on 1 December 1994. The **RUBY E.** rested at 83 feet and had a maximum height above the sand of 31 feet with visibility of 40 feet on the dive.

### Biological Data (Biotic Communities)

*Fishes*

Many of the fish species common on nearshore reefs in southern California (Wilson *et al.* 1990) were observed on each of the modules surveyed (Tables 2 and 3). Blacksmith (*Chromis punctipinnis*) was the most numerous at all modules. Adult, juvenile, and young-of-year (YOY) blacksmith were observed in abundant numbers at all modules. Another fish observed in abundant numbers on some, but not all modules was the señorita wrasse (*Oxyjulis californica*). Adults, juveniles, and YOY were found in abundant numbers on all modules except for the deep module at PBAR where señorita were only common, and OAR1 and PBAR mid-depth module where señorita were absent. Black croaker (*Cheilotrema saturnum*), sargo (*Anisotremus davidsonii*), kelp bass (*Paralabrax clathratus*), and barred sand bass (*Paralabrax nebulifer*) were the only other species that were found in abundant numbers at one or more modules. A variety of other species were found at the artificial reefs (Tables 3 through 6).

The fewest species (6) were found on OAR1, which was the deepest reef surveyed and also had the lowest relief. The same six species plus blackeye goby and black croaker were observed in 1985 (Wilson and Togstad 1985). All six species were present as adults, three were present as juveniles, and one was present as YOY.

The greatest number of species, 17, were observed at the shallow and deep modules on OAR2, (11 and 14 species were observed in 1992 respectively), and the mid-depth module at CAR (20 species in 1992). The shallow and deep modules at OAR2 each had 17 species of fish. The mid-depth module at OAR2 had 14 species of fish. Fifteen species on the shallow module were represented by adults; 13 were present as juveniles; four were present as YOY. The mid-depth

module had 13 species of fish present as adults, six as juveniles, and one as YOY. The deep module had 15 species with adults, six with juveniles, and one with YOY.

The mid-depth module at CAR had 17 species of fish. Twenty species were identified in 1992 (Bedford 1993). Of these 14 were present as adults, 13 as juveniles, and one as YOY. All 14 species at the shallow module were present as adults, ten were present as juveniles, and four were present as YOY. Of the 13 deep module species, 12 were present as adults, ten were present as juveniles and five were present as YOY.

At PBAR, all 13 species at the shallow module were present as adults, nine were present as juveniles, and 1 as YOY. All 11 mid-depth module species were present as adults, six as juveniles, and one as YOY. The deep module had 15 species, all of which were present as adults, eight as juveniles, and one as YOY.

The **Ruby E.** at MBAR had 15 species of fish. Twelve species were present in 1992 (Bedford 1993). Thirteen of the 15 species present in 1994 were present as adults, 11 as juveniles, and 1 was present as YOY.

*Macroinvertebrates*

The number of macroinvertebrate species observed at the five reefs ranged from two to seven per module (Tables 3-6). Four macroinvertebrate species were found at OAR1 with *Pisaster ochraceus* being the most common.

The shallow module at OAR2 had seven macroinvertebrate species, the most found on any module. Hermit crabs, *Pagurus,* were the most common species at the shallow module, the giant keyhole limpet, *Megathura crenulata*, at the mid-depth module and *P. giganteus* at the deep module.

The mid-depth module at CAR, the youngest reef, had 2 macroinvertebrate species, the fewest of all modules. Hermit crabs were the most common macroinvertebrate at the shallow module and *P. giganteus* was the most common macroinvertebrate species on the mid-depth and deep modules.

The shallow module at PBAR had four macroinvertebrate species dominated by lobsters, *Panulirus interruptus*. Six species were found at the mid-depth and deep modules which were both dominated by hermit crabs. Lobsters were also seen at each of these modules.

MBAR had four macroinvertebrate species with rock scallops, Hinnites sp., being the most common.

*Turf Community*

Turf communities varied among the five reefs (tables 3-6). For example, turf invertebrates at the oldest reef, OAR1, were dominated by strawberry anemones, *Corynactis californica*, while erect ectoprocts (primarily *Bugula* sp.) dominated CAR, the youngest reef. No turf algae were found at OAR1.

The mid-depth module at OAR2 had the most turf invertebrates (16) of all the reefs surveyed. Erect ectoprocts and strawberry anemone were classified as being commonly found on the mid-depth and deep modules, while erect ectoprocts and strawberry anemones were occasionally found on the shallow module.

The turf community at all 3 CAR modules were dominated by erect ectoprocts. The deep module at CAR had 8 taxa of turf algae while the mid-depth and shallow modules had 6 and 4 taxa respectively.

The shallow module at PBAR had the fewest (4) turf invertebrate species of all reefs surveyed. Filamentous red algal turf was categorized as abundant at PBAR.

Filamentous red algal turf was also categorized as abundant at MBAR. The **RUBY E.** at MBAR had eight taxa of turf algae.

*Macroalgae*

Giant kelp, *Macrocystis pyrifera*, was found at all reefs except MBAR and PBAR. OAR1 had a few small kelp plants despite its 95' depth. OAR2 had kelp, *Pterygophora*, and *Desmarestia.* CAR had the most abundant kelp, some of which almost reached the surface. *Laminaria* and *Desmarestia* were also very common at CAR.

## Discussion

The number of fish species on reefs surveyed in this study are generally within the range of 10-19 species found for southern California artificial reefs found in previous surveys (Ambrose and Swarbrick, 1989). This is especially true if the species at the different modules are combined for a given reef.

OAR1, the oldest reef surveyed this year, was constructed almost 31 years ago. The composition of its turf community illustrates its maturity. Late successional taxa such as strawberry anemones, large red and golden gorgonians, and encrusting sponges (Palmer-Zwhalen & Aseltine, 1994) dominated this community while mud ectoprocts and other early colonizers were absent from the quadrats sampled.

OAR1 was last surveyed in 1985. At that time, the reef was 20 years old and had a well-established biological community (Wilson and Togstad 1985). Gorgonians, strawberry anemones, and sponges were approximately as common as at present. The large size of the slow-growing gorgonians, described as late colonizers by Palmer-Zwahlen in 1994, would discount heavy sand scouring or burial. Wilson and Togstad (1985) found some patches of heavy silt deposition which could act to suffocate some members of the turf community and allow mussels and barnacles to periodically recolonize the reef. Silt could originate from winter runoff from the nearby San Luis Rey and Santa Margarita Rivers.

No barnacles were found in the 1994 survey. Nor were any burrowing or rose anemones, *Tealia piscivora*, which were common in 1985. Turf algae, notably *Desmarestia* and *Acrosorium*, were also lacking compared to the 1985 survey. Some kelp was seen in the present survey and juvenile blacksmith, kelp bass, and sheephead were also present. Essentially, OAR1 was not much different in 1994 compared to 1985. It still provided habitat for sheephead, sculpin, and bass; protection for blacksmith and other recruits; and a stable substrate for an established turf community. In 1985 OAR1 had eight fish species, including the same six found in 1994. Blackeye goby and black croaker were present in 1985, but not in 1994. Blackeye gobies are relatively small and can be easily missed while we have observed black croakers to be transitory and long term residents at other reefs. OAR1 probably reached a community equilibrium state many years ago.

OAR2 has undergone relatively more changes than OAR1 since it was last surveyed. For example, in 1990 the mud ectoproct, an early colonizer, was categorized as common to abundant on all modules and barnacles were categorized as occasional to common. By 1992, no mud ectoprocts were observed, mussels were rare, and barnacles were still common. In the 1994 survey no mud ectoprocts or mussels were observed and only barnacle remains were noted. The shallow and mid-depth modules had kelp surface canopy in 1990. In 1992 canopy was absent from the reef and individual kelp plants were very rare. The 1994 survey indicated that kelp is once again recruiting to the reef. Kelp densities on the mid-depth module were 0.42 plants per $m^2$, up from 0.05 $m^2$ in 1992.

The number of fish species on OAR2 has increased over time. The shallow module in 1990 had 11 species, 14 in 1992 and 17 in 1994. The mid-module had 13 species in 1990, 11 in 1992, and 14 in 1994. The deep module (not surveyed in 1990), had 11 species in 1992 and 17 in 1994.

What may be more significant than the increase in species is the increase in the number of juvenile and young-of-the-year (YOY) fish. In 1990, only juvenile blacksmith and garibaldi were present. In 1992, juvenile sheephead, señorita, and kelp bass as well were observed. In 1994 eight additional species were observed (black croaker, jack mackerel, barred sand bass,

black surfperch, pile surfperch, sculpin, rock wrasse, and white surfperch). Except for the pelagic, non-resident jack mackerel, the reef is apparently providing new nursery habitat for these species. Since smaller-sized fish are much less likely to have crossed open sand habitat to reach the reef, they probably settled out of the plankton (except for live-bearing surfperch) and grew on the reef. The increasing habitat maturity of OAR2, as evidenced by the diversifying invertebrate turf community, may be responsible for the additional number of juveniles on the reef. OAR2 may be nearing a community equilibrium condition.

The increasing maturity of CAR was also evident from the changes in species and relative abundances of the fish, turf, macroalgal and macroinvertebrate communities. The most noticible change in the fish community was the increase in species which had juveniles on the reef. In 1992, eight fish species had juveniles on CAR while ten species had juveniles in 1994. Black croaker, sculpin, and sargo were additional species in 1994 while the blackeye goby present in 1992 were not seen.

There was little change in the number of fish species between the two most recent surveys. The shallow module had 14 species in both 1992 and 1994. The mid-depth module supported 20 species in 1992 and 17 in 1994. The deep module had 14 species in 1992 and 13 in 1994.

Change is more obvious in the turf, macroalgal and invertebrate communities at CAR. In 1992, gorgonians were absent; turf algae were rare; *Macrocystis*, and *Laminaria* were < .05/m$^2$; mussels were present on all modules; diatoms and barnacles were categorized as occasional. In 1994, gorgonians were categorized as occasional; mussels and barnacles rare (present only on the shallow module); diatoms absent; turf algae common and *Macrocystis* counts as high as 5.51/m$^2$ (*Desmarestia*, *Laminaria*, and *Pterygophora* had counts ranging from .04 to 3.20/m$^2$).

The macroalgal cover at CAR is the most persistent of the artificial reefs in southern California built by the CDFG. Kelp has recruited and disappeared repeatedly on other reefs, yet has continued to increase on CAR. CAR's proximity (<0.25 miles) to upcoast and downcoast natural kelp beds, which can supply spores and drift plants may be the key to kelp persistence. It will be interesting to follow CAR in the near future to see if the longer lived species, like strawberry anemones and gorgonians, replace kelp, as has happened on other reefs, or if a kelp-dominated equilibrium is reached.

In contrast, macroalgae on PBAR does not follow the general trend of increasing abundance with time. In 1988, a dive team from MBC Applied Environmental Sciences surveyed PBAR and noted that "there were significant numbers of recently recruited *Macrocystis* and *Pterygophora* on almost all modules. Assuming these plants survive, they should significantly increase the productivity of the reefs, and provide additional habitat in the near future" (MBC, 1988). In 1990, one module had a canopy and macroalgae were on all modules. Macroalgae were still on all modules in 1992, but no macroalgae were found in the current survey. This is somewhat unexpected given the relatively close proximity (<0.5 miles) of the extensive La Jolla kelp beds.

Foliose red algae abundance increased over time. In 1988, MBC found low growing reds to be common on the upper regions of all the modules. Our 1990 survey categorized foliose reds as occasional. By 1992, they were categorized as abundant and remained so in 1994.

Further evidence of the increasing maturity of PBAR is indicated by changes in the abundances of mud ectoprocts and barnacles. In 1990 barnacles and mud ectoprocts were abundant on the mid-depth and deep

modules. In 1992, the mud ectoproct was abundant on the shallow module only and no barnacles were observed. By 1994, neither mud ectoprocts nor live barnacles were seen, although dead barnacles were seen on the deep module.

PBAR has one of the least diverse turf invertebrate communities of the reefs surveyed in 1994. The shallow and mid-depth modules of PBAR each have 5 taxa of turf invertebrates, while the deep module has 7 taxa which is much less than most of the other reefs surveyed (tables 3-6). The number of turf invertebrate taxa had increased from 3 in 1990 to 7 in 1992.

PBAR does have the highest incidence of lobsters, however. Juvenile lobsters were "abundant on all reef modules" according to MBC in 1988. That trend continued in 1990, 1992, and in 1994 where they were found in abundances as high as 1.74 per square meter. A possible reason for the depauperate turf and macroalgal communities on this reef is intense foraging by lobsters.

The number of fish species on PBAR is comparable to the other quarry rock reefs surveyed. Eleven species of fish were observed by MBC on PBAR in 1988. The shallow module had 13 species in 1990, 20 species in 1992 and 15 species in 1994. The mid-depth module had 14 species in 1990, 17 in 1992, and 11 in 1994. The deep module had 13 species in 1990, 18 species in 1992, and 13 species in 1994.

In 1990, only blacksmith were observed as juveniles. By 1992, seven more species of fish had juveniles on the reef: señorita, sheephead, blackeye goby, black surfperch, olive rockfish, brown rockfish, and rubberlip perch. Eight species, including painted greenling, had juveniles on the reef in 1994. Due to its apparent slow development compared to other reefs of the same age, PBAR may still be a few years away from having a stable community.

MBAR is the only one of the five artificial reefs surveyed this year constructed of material other than quarry rock. The "module" surveyed consists of the steel hull of a 165 foot former U.S. Coast Guard cutter **RUBY E**. Despite its distinctive structure, the associated fish community is similar to the other artificial reefs. Eleven of the 15 fish species on the **RUBY E** had juvenile size classes. Three of the 12 fish species found on the ship in 1992 had juveniles present. Larger schools of jack mackerel and sardines were found on the **RUBY E** relative to the other reefs, possibly because of its 31 feet of relief. The other reefs have no more than 11 feet of relief.

The macroinvertebrate community on the **RUBY E**. is not as developed as on some of the other modules of similar depth. There were fewer species and fewer individuals than on OAR1 and PBAR, but similar numbers to the deep modules on CAR and OAR2. Starfish were present on the hull in 1992, but not on the sampling transects. Starfish were presumably more abundant in 1994 because they occurred on the sampling transect.

*Macrocystis* and *Agarum* were present ($0.20/m^2$ and $0.125/m^2$ respectively) in the 1992 survey, but macroalgae were absent in the 1994 survey.

The invertebrate turf community was also somewhat limited. The broad, flat, hull and deck surfaces which make up the bulk of the ship do not support a well developed turf community. Erect ectoprocts were the most common turf invertebrate in 1992 and were still the most common turf invertebrate in 1994. Cup corals and tunicates are becoming more common over time. Gorgonians were absent in 1992 and were rare in 1994. Strawberry anemones were more common in 1994 than in 1992, but they seem concentrated on the ladderwells, support cables, and other intricate features of the ship. It is ironic that barnacles, the nemesis of ships when they are afloat, were

absent from quadrats sampled in the 1992 and 1994 surveys.

Filamentous red algae were abundant in 1994 where as in 1992 they were common. Crustose reds have become more common over time while foliose reds such as *Rhodymenia* have become less so.

Previous experiences with sunken vessels in California has lead the Department of Fish & Game to view them as less useful than other reef materials in providing productive habitat for marine organisms. It is expected that over time the **RUBY E.** will continue to support a community that is less diverse than other artificial reefs. Currently, however, it is a very popular location with dive and angling enthusiasts alike.

In conclusion, the 5 reefs surveyed in this report continue to perform as expected. Lobster trappers set 1 to 5 traps per module on almost all the reefs during the season. Private vessels and charter boats can be seen fishing on many of the reefs on any given day. Young fish and invertebrates recruit to the reefs while older cohorts reside and seek shelter on the reefs. The algal and invertebrate communities of the younger reefs are increasing in diversity and maturity. In a sense, these artificial reefs are becoming less artificial over time.

## LITERATURE CITED


Ambrose, R. F. and S. L. Swarbrick. 1989. Composition of fish assemblages on artificial and natural reefs off the coast of southern California. Bull. Mar. Sci. 44(2):718-733.

Anderson, T. W., E. E. DeMartini and D. A. Roberts. 1989. Relationship between habitat structure, body size and distribution of fishes at a temperate artificial reef. Bull. Mar. Sci. 44(2):681-697.

Bedford, D. W. 1993. A report of biological observations at Oceanside #1 and #2 Artificial Reefs, Carlsbad Artificial Reef, Pacific Beach Artificial Reef, and Mission Bay Park Artificial Reef.

Carlisle, J. G., C. H. Turner and E. E. Ebert. 1964. Artificial habitat in the marine environment. Calif. Dept. Fish and Game. Fish Bull. 124. 93p.

Carter, J. W., A. L. Carpenter, M. S. Foster and W. N. Jessee. 1985. Benthic succession on an artificial reef designed to support a kelp-reef community. Bull. Mar. Sci. 37(1):86-113.

Hueckel, G. J. and R. M. Buckley. 1989. Predicting fish species on artificial reefs using indicator biota from natural reefs. 44(2):873-880.

Lewis, R. D. and K. K. McKee. 1989. A guide to the artificial reefs of southern California. Sport Fish Restoration Program, California Department of Fish and Game. 73 pgs.

Lewis, R. D., K. C. Wilson and K. K. McKee. 1989. A report of biological observations at Topanga Artificial Reef. Report to the California Coastal Commission. 9 pgs.

Matthews, K. R. 1985. Species similarity and movement of fishes on natural and artificial reefs in Monterey Bay, California. Bull. Mar. Sci. 37(1):252-270.

MBC Applied Environmental Sciences. 1988. Survey of the Pacific Beach Artificial Reef Complex. Report prepared for the California Department of Fish and Game.

Palmer-Zwahlen, M. and D. Aseltine. 1994. Successional development of the turf community on a quarry rock artificial reef. Bull. Mar. Sci. 55(2-3): 902-923.

Quast, J. C. 1968. Observations on the food of kelp bed fishes. In: W. J. North and C. L. Hubbs (eds.). Utilization of kelp bed resources in southern California. Calif. Dept. Fish and Game. Fish Bull. 139. pp. 109-141.

Solonsky, A. C. 1985. Fish colonization and the effects of fishing activities on two artificial reefs in Monterey Bay, California. Bull. Mar. Sci. 37(1):336-347.

Turner, C. H., E. E. Ebert and R. R. Given. 1969. Man made reef ecology. Calif. Dept. Fish and Game. Fish Bull. 146. 221 p.

Wilson, K. C. And H. A. Togstad. 1985. Oceanside Artificial Reef reconnaissance dive.

Wilson, K. C., R. D. Lewis and H. A. Togstad. 1990. Artificial Reef Plan for Sport Fish Enhancement. Calif. Dept. Fish and Game. Admin. Rpt. 90-15. 76 p.

## Physical Characteristics

| MODULE | MATERIAL | YEAR CONSTRUCTED | DEPTH (feet) | MODULE HEIGHT (feet) | VISIBILITY (feet) |
|---|---|---|---|---|---|
| OCEANSIDE #2 | 10,000 tons quarry rock | 1987 | | | |
| 4C | | | 48 | 8 | 10 |
| 4B | | | 64 | 9 | 20 |
| 4A | | | 72 | 8 | 15-25 |
| OCEANSIDE #1 | 2,000 tons quarry rock | 1964 | | | |
| G | | | 95 | 5 | 20-30 |
| CARLSBAD | 10,000 tons quarry rock | 1991 | | | |
| 1 | | | 43 | 7 | 5-25 |
| 5 | | | 46 | 9 | 3-15 |
| 9 | | | 58 | 9 | 10 |
| PACIFIC BEACH | 10,000 tons quarry rock | 1987 | | | |
| 1A | | | 76 | 10 | 25 |
| 2B | | | 60 | 11 | 40 |
| 4C | | | 47 | 9 | <10 |
| MISSION BAY | 165' x 38' x 33' US Coast Guard cutter | 1989 | | | |
| RUBY E. | | | 83 | 31 | 40 |

**Table 1.**

## Number of fish species observed.

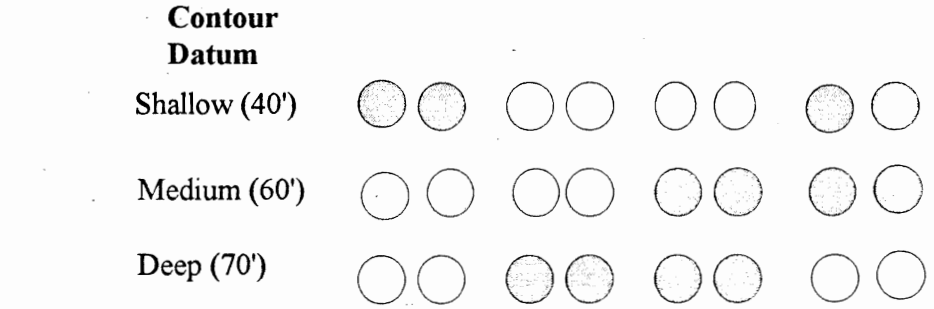
| | YEAR | | | | |
|---|---|---|---|---|---|
| REEF | 1985 | 1988 | 1990 | 1992 | 1994 |
| OCEANSIDE #1 | 8 | | | | 6 |
| OCEANSIDE #2 | | | | | |
| 4C | | | 11 | 14 | 17 |
| 4B | | | 13 | 11 | 14 |
| 4A | | | no data | 11 | 17 |
| CARLSBAD | | | | | |
| 1 | | | | 14 | 14 |
| 5 | | | | 20 | 17 |
| 9 | | | | 14 | 13 |
| PACIFIC BEACH | | (11)* | | | |
| 1A | | | 13 | 18 | 13 |
| 2B | | | 14 | 17 | 11 |
| 4C | | | 13 | 20 | 15 |
| MISSION BAY | | | | 12 | 15 |

**composite of all modules*

*For perspective compare to Ambrose & Swarbrick's 1989 study which looked at natural and artificial reefs and found that artificial reefs had 13-21 species (18.7 avg) and natural reefs had 10-19 species (14.2 avg).*

**Table 2.**

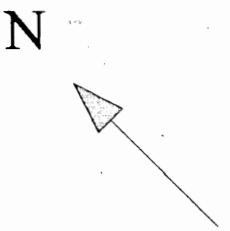
## Experimental Reef Design




low relief: 5 feet or small rock: diameter 1'-3'

high relief: 10 feet or large rock: diameter 4'-6'

Module dimensions: 50 ft diameter
Distance within a pair of modules: 50 ft
Distance between a pair of modules: 600 ft




*not to scale

Figure 2

| MISSION BAY | | | OCEANSIDE #1 | | |
|---|---|---|---|---|---|
| | Deep module: Ruby E (83 feet) | | | Deep module: Oceanside #1 (95 feet) | |
| FISHES | Abundance Estimate | Size Estimate | FISHES | Abundance Estimate | Size Estimate |
| Barred sand bass | abundant | A,J | Barred sand bass | abundant | A |
| Blacksmith | abundant | A,J,Y | Blacksmith | abundant | A,J,Y |
| Jack mackerel | abundant | J | Kelp bass | common | A,J |
| Kelp bass | abundant | A,J | Sheephead | common | A,J |
| Señorita | abundant | A,J | Sculpin | occasional | A |
| Black surfperch | common | A,J | Treefish | occasional | A |
| Pacific sardine | common | J | | | |
| Painted greenling | common | A,J | | | |
| White surfperch | common | A,J | | | |
| Blackeye goby | occasional | A | | | |
| Halfmoon | occasional | A | | | |
| Pile surfperch | occasional | A,J | | | |
| Rainbow perch | occasional | A | | | |
| Rubberlip perch | occasional | A | | | |
| Sheephead | occasional | A,J | | | |
| MACROINVERTEBRATES | | # per m² | MACROINVERTEBRATES | | # per m² |
| *Pisaster ochraceus* | | 0.44 | Rock scallop | | 0.57 |
| *Parastichopus* | | 0.03 | Sheep crab | | 0.57 |
| *Pisaster brevispinus* | | 0.03 | *Pisaster giganteus* | | 0.16 |
| Sheep crab | | 0.03 | *Megathura* | | 0.08 |
| TURF COMMUNITY | | Abundance Estimate | TURF COMMUNITY | | Abundance Estimate |
| Invertebrates | | | Invertebrates | | |
| Cup coral (orange) | | occasional | Strawberry anemone | | common |
| Erect ectoprocts | | occasional | Encrusting sponge | | occasional |
| Hydroids (ostrich plume) | | occasional | Encrusting sponges | | occasional |
| Hydroids (total) | | occasional | Erect ectoprocts | | occasional |
| Strawberry anemone | | occasional | Gorgonian (golden) | | occasional |
| Tunicates (other) | | occasional | Gorgonian (red) | | occasional |
| Tunicates (total) | | occasional | Hydroid (other) | | occasional |
| Gorgonian (red) | | rare | Hydroid (total) | | occasional |
| | | | Tunicate (other) | | occasional |
| | | | Tunicate (total) | | occasional |
| | | | Cup coral (orange) | | rare |
| Algae | | | Algae | | |
| Filamentous reds | | abundant | | | |
| Crustose reds | | occasional | | | |
| *Dictyota* | | occasional | | | |
| Foliose reds | | occasional | | | |
| *Gigartina* | | occasional | | | |
| *Rhodymenia* | | occasional | | | |
| *Botryocladia* | | rare | | | |
| *Corallina* | | rare | | | |
| MACROALGAE | # per m² | Size Estimate | MACROALGAE | # per m² | Size Estimate |
| | | | *Macrocystis* | 0.33 | A1, A2 |

Table 3

Abundance estimates for fishes are abundant =>50; common= 11-50; occasional = 2-11; and one = 1.

Size estimates: A=adult, J=juvenile, and Y=young of the year.

Abundance estimates for turf community are: abundant = >50% cover,common = 11-50% cover, occasional = 2-11% cover, and rare =<2% cover.

## OCEANSIDE #2

| Shallow module: 4C (48 feet) | | | Mid-depth module: 4B (64 feet) | | | Deep module: 4A (72 feet) | | |
|---|---|---|---|---|---|---|---|---|
| FISHES | Abundance Estimate | Size Estimate | FISHES | Abundance Estimate | Size Estimate | FISHES | Abundance Estimate | Size Estimate |
| Black croaker | abundant | A,J | Black croaker | abundant | A | Black croaker | abundant | A |
| Blacksmith | abundant | A,J,Y | Blacksmith | abundant | A,J,Y | Blacksmith | abundant | A,J,Y |
| Jack mackerel | abundant | J | Jack mackerel | abundant | J | Jack mackerel | abundant | J |
| Sargo | abundant | A,J,Y | Barred sand bass | common | A,J | Pacific sardines | abundant | A |
| Señorita | abundant | A,J,Y | Black surfperch | common | A,J | Barred sand bass | common | A,J |
| Barred sand bass | common | A,J | Halfmoon | common | A | Black surfperch | common | A |
| Black surfperch | common | A,J | Kelp bass | common | A,J | Kelp bass | common | A,J |
| Kelp bass | common | A,J,Y | Pile surfperch | common | A | Pile surfperch | common | A |
| Pile surfperch | common | A,J | Sargo | common | A | Sargo | common | A |
| Sheephead | common | A,J | Sculpin | common | A | Sculpin | common | A |
| Garibaldi | occasional | A | Sheephead | common | A,J | Sheephead | common | A,J |
| Halfmoon | occasional | A | Garibaldi | occasional | A | Blackeye goby | occasional | A |
| Rock wrasse | occasional | A,J | Rubberlip perch | occasional | A | Halfmoon | occasional | A |
| Rubberlip perch | occasional | A | CA Halibut | one | A | Rock wrasse | occasional | A |
| Sculpin | occasional | A,J | | | | Rubberlip perch | occasional | A |
| White surfperch | occasional | J | | | | Señorita | occasional | A,J |
| Painted greenling | one | A | | | | Bluebanded goby | one | A |
| **MACROINVERTEBRATES** | | **# per m²** | **MACROINVERTEBRATES** | | **# per m²** | **MACROINVERTEBRATES** | | **# per m²** |
| Hermit crabs | | >39.22 | *Pisaster giganteus* | | 0.30 | *Pisaster giganteus* | | 0.27 |
| *Pisaster giganteus* | | 0.43 | *Panulirus interruptus* | | 0.24 | *Panulirus interruptus* | | 0.14 |
| *Panulirus interruptus* | | 0.31 | *Megathura* | | 0.12 | *Pisaster brevispinus* | | 0.07 |
| *Megathura* | | 0.12 | *Pisaster brevispinus* | | 0.12 | | | |
| *Pisaster brevispinus* | | 0.04 | | | | | | |
| *Pisaster ochraceus* | | 0.04 | | | | | | |
| *Stronglyocentrotus franciscanus* | | 0.04 | | | | | | |
| **TURF COMMUNITY** | | **Abundance Estimate** | **TURF COMMUNITY** | | **Abundance Estimate** | **TURF COMMUNITY** | | **Abundance Estimate** |
| Invertebrates | | | Invertebrates | | | Invertebrates | | |
| Erect ectoprocts | | occasional | Erect ectoprocts | | common | Encrusting sponges | | common |
| Hydroids (other) | | occasional | Strawberry anemone | | common | Erect ectoprocts | | common |
| Hydroids (total) | | occasional | Encrusting sponges | | occasional | Strawberry anemone | | common |
| Strawberry anemone | | occasional | Hydroid (ostrich plume) | | occasional | Barnacles (dead) | | occasional |
| Gorgonian (golden) | | occasional | Hydroid (other) | | occasional | Hydroid (ostrich plume) | | occasional |
| Parchment tube worm | | occasional | Hydroid (total) | | occasional | Hydroid (other) | | occasional |
| Cup coral (orange) | | occasional | Parchment tube worm | | occasional | Hydroid (total) | | occasional |
| Tunicates (other) | | occasional | Tunicate (other) | | occasional | Mud ectoproct | | occasional |
| Tunicates (total) | | occasional | Tunicate (total) | | occasional | Tunicate (other) | | rare |
| Gorgonian (brown) | | occasional | Anemone (unidentified) | | rare | Tunicate (stalked) | | rare |
| Hermit crabs | | occasional | Cup coral (orange) | | rare | Tunicate (total) | | rare |
| Scaled worm mollusk | | occasional | Encrusting bryozoan | | rare | | | |
| Rock scallop | | 0.3m² | Erect sponge | | rare | | | |
| | | | Gorgonian (brown) | | rare | | | |
| | | | Gorgonian (golden) | | rare | | | |
| | | | Nudibranch | | rare | | | |
| | | | Scaled worm mollusk | | rare | | | |
| | | | Tunicate (stalked) | | rare | | | |
| Algae | | | Algae | | | Algae | | |
| *Rhodymenia* | | occasional | Filamentous red | | common | *Desmarestia* | | occasional |
| *Gigartina* | | occasional | *Rhodymenia* | | occasional | *Microcladia* | | occasional |
| *Callophyllis* | | occasional | *Microcladia* | | rare | *Rhodymenia* | | occasional |
| *Dictyota* | | occasional | | | | | | |
| *Desmarestia* | | occasional | | | | | | |
| *Acrosorium* | | occasional | | | | | | |
| Filamentous reds | | occasional | | | | | | |
| **MACROALGAE** | **# per m²** | **Size Estimate** | **MACROALGAE** | **# per m²** | **Size Estimate** | **MACROALGAE** | **# per m²** | **Size Estimate** |
| *Desmarestia* | 1.41 | A2,A1 | *Macrocystis* | 0.42 | A2,A1 | *Desmarestia* | 3.20 | A2 |
| *Macrocystis* | 0.04 | A2 | *Desmarestia* | 0.12 | A1 | *Macrocystis* | 0.07 | A2 |
| *Pterygophora* | 0.04 | A1 | | | | | | |

Table 4

Abundance estimates for fishes are abundant =>50; common= 11-50; occasional = 2-11; and one = 1.

Size estimates: A=adult, J=juvenile, and Y=young of the year.

Abundance estimates for turf community are: abundant = >50% cover,common = 11-50% cover, occasional = 2-11% cover, and rare =<2% cover.

## CARLSBAD

| Shallow module: 1 (43 feet) | | |
|---|---|---|
| FISHES | Abundance Estimate | Size Estimate |
| Blacksmith | abundant | A,J,Y |
| Señorita | abundant | A,J,Y |
| Black croaker | common | A,J |
| Black surfperch | common | A,J |
| Halfmoon | common | A |
| Kelp bass | common | A,J,Y |
| Rock wrasse | common | A |
| Sargo | common | A,J,Y |
| Sheephead | common | A,J |
| Garibaldi | occasional | A,J |
| Kelpfish | occasional | A |
| Sculpin | occasional | A,J |
| White seabass | occasional | A |
| White surfperch | occasional | A,J |
| **MACROINVERTEBRATES** | **# per m²** | |
| Hermit crab | 2.64 | |
| *Kelletia* | 0.65 | |
| *Panulirus interruptus* | 0.49 | |
| *Pisaster giganteus* | 0.33 | |
| *Aplysia* | 0.04 | |
| Rock scallop | 0.04 | |
| **TURF COMMUNITY** | **Abundance Estimate** | |
| **Invertebrates** | | |
| Erect ectoprocts | common | |
| Gem murex | occasional | |
| Parchment tube worm | occasional | |
| Scaled worm mollusk | occasional | |
| Tunicates (other) | occasional | |
| Tunicates (total) | occasional | |
| Cup coral (orange) | rare | |
| Gorgonian (brown) | rare | |
| Gorgonian (golden) | rare | |
| Hydroids (ostrich plume) | rare | |
| Hydroids (total) | rare | |
| Kellet's whelk | rare | |
| Striped acorn barnacle | rare | |
| Tunicate (stalked) | rare | |
| Mussel | rare | |
| Rock scallop | 0.67m² | |
| **Algae** | | |
| *Corallina* | common | |
| *Laminaria* | common | |
| *Rhodymenia* | common | |
| *Macrocystis* | occasional | |
| **MACROALGAE** | **# per m²** | **Size Estimate** |
| *Macrocystis* | 3.66 | A2,A1 |
| *Desmarestia* | 1.34 | A2 |
| *Laminaria* | 0.33 | A2,A1 |
| *Pterygophora* | 0.20 | A2 |

| Mid-depth module: 5 (46 feet) | | |
|---|---|---|
| FISHES | Abundance Estimate | Size Estimate |
| Black croaker | abundant | A,J |
| Blacksmith | abundant | A,J,Y |
| Sargo | abundant | A,J |
| Señorita | abundant | A,J |
| Black surfperch | common | A,J |
| CA Barracuda | common | J |
| Kelp bass | common | A,J |
| Rock wrasse | common | A,J |
| Sheephead | common | A,J |
| Garibaldi | occasional | A,J |
| Halfmoon | occasional | A |
| Opaleye | occasional | A |
| Salema | occasional | J |
| White surfperch | occasional | A,J |
| Barred sand bass | one | A |
| Kelpfish | one | A |
| Rainbow perch | one | J |
| **MACROINVERTEBRATES** | **# per m²** | |
| *Pisaster giganteus* | 0.82 | |
| *Pisaster brevispinus* | 0.04 | |
| **TURF COMMUNITY** | **Abundance Estimate** | |
| **Invertebrates** | | |
| Erect ectoprocts | common | |
| Encrusting sponges | occasional | |
| Gorgonian (golden) | occasional | |
| Scaled worm mollusk | occasional | |
| Striped acorn barnacle | occasional | |
| Cup coral (orange) | rare | |
| Gorgonian (brown) | rare | |
| Hydroid (ostrich plume) | rare | |
| Hydroid (total) | rare | |
| Kellet's whelk | rare | |
| **Algae** | | |
| *Corallina* | common | |
| *Eisenia* | common | |
| *Macrocystis* | common | |
| *Rhodymenia* | common | |
| *Plocamium* | occasional | |
| *Botryocladia* | rare | |
| **MACROALGAE** | **# per m²** | **Size Estimate** |
| *Laminaria* | 5.51 | A2 |
| *Macrocystis* | 1.35 | A2 |
| *Desmarestia* | 1.10 | A2 |
| *Pterygophora* | 0.04 | A2 |

| Deep module: 9 (58 feet) | | |
|---|---|---|
| FISHES | Abundance Estimate | Size Estimate |
| Black croaker | abundant | A,J |
| Blacksmith | abundant | A,J,Y |
| Señorita | abundant | A,J,Y |
| Black surfperch | common | A,J |
| Kelp bass | common | A,J,Y |
| Rock wrasse | common | A,J |
| Sargo | common | A,J,Y |
| Sheephead | common | A,J |
| Halfmoon | occasional | A,J |
| Opaleye | occasional | A |
| Pile surfperch | occasional | A |
| White surfperch | occasional | J,Y |
| Brown rockfish | one | A |
| **MACROINVERTEBRATES** | **# per m²** | |
| *Pisaster giganteus* | 0.27 | |
| *Panulirus interruptus* | 0.14 | |
| *Pisaster brevispinus* | 0.07 | |
| **TURF COMMUNITY** | **Abundance Estimate** | |
| **Invertebrates** | | |
| Erect ectoprocts | common | |
| Encrusting sponges | occasional | |
| Gorgonian (golden) | occasional | |
| Hydroid (ostrich plume) | occasional | |
| Hydroid (total) | occasional | |
| Strawberry anemone | occasional | |
| Cup coral (orange) | rare | |
| Tunicate (other) | rare | |
| Tunicate (stalked) | rare | |
| Tunicate (total) | rare | |
| **Algae** | | |
| *Corallina* | common | |
| *Laminaria* | common | |
| *Rhodymenia* | common | |
| *Callophyllis* | occasional | |
| *Cystoseira* | occasional | |
| *Macrocystis* | occasional | |
| *Pterygophora* | occasional | |
| *Botryocladia* | rare | |
| **MACROALGAE** | **# per m²** | **Size Estimate** |
| *Desmarestia* | 3.20 | A2 |
| *Macrocystis* | 0.07 | A2 |

Table 5

Abundance estimates for fishes are abundant =>50; common= 11-50; occasional = 2-11; and one = 1.

Size estimates: A=adult, J=juvenile, and Y=young of the year.

Abundance estimates for turf community are: abundant = >50% cover,common = 11-50% cover, occasional = 2-11% cover, and rare =<2% cover.

## PACIFIC BEACH

| Shallow module: 4C (47 feet) | | | Mid-depth module: 2B (60 feet) | | | Deep module: 1A (76 feet) | | |
|---|---|---|---|---|---|---|---|---|
| FISHES | Abundance Estimate | Size Estimate | FISHES | Abundance Estimate | Size Estimate | FISHES | Abundance Estimate | Size Estimate |
| Blacksmith | abundant | A,J,Y | Blacksmith | abundant | A,J,Y | Blacksmith | abundant | A,J,Y |
| Señorita | abundant | A,J | Barred sand bass | common | A,J | Barred sand bass | common | A,J |
| Barred sand bass | common | A,J | Black surfperch | common | A,J | Kelp bass | common | A,J |
| Kelp bass | common | A,J | Blackeye goby | common | A | Señorita | common | A,J |
| Pile surfperch | common | A,J | Halfmoon | common | A | Sheephead | common | A,J |
| Sheephead | common | A,J | Kelp bass | common | A,J | Black croaker | occasional | A |
| White surfperch | common | A,J | Sheephead | common | A,J | Black surfperch | occasional | A,J |
| Black surfperch | occasional | A,J | Painted greenling | occasional | A,J | Blackeye goby | occasional | A |
| Blackeye goby | occasional | A | Rock wrasse | occasional | A | Garibaldi | occasional | A |
| Halfmoon | occasional | A | Sculpin | occasional | A | Halfmoon | occasional | A,J |
| Rock wrasse | occasional | A | White surfperch | occasional | A | Opaleye | occasional | A |
| Sculpin | occasional | A | | | | Painted greenling | occasional | A,J |
| Painted greenling | one | A,J | | | | Rubberlip perch | occasional | A |
| | | | | | | Sculpin | occasional | A |
| | | | | | | Moray eel | one | A |
| MACROINVERTEBRATES | | # per m² | MACROINVERTEBRATES | | # per m² | MACROINVERTEBRATES | | # per m² |
| *Panulirus interruptus* | | 1.74 | Hermit crabs | | 2.65 | Hermit crabs | | 2.86 |
| *Pisaster giganteus* | | 0.53 | Kelletia | | 0.82 | *Kelletia* | | 0.38 |
| *Megathura* | | 0.21 | *Pisaster giganteus* | | 0.61 | *Pisaster giganteus* | | 0.28 |
| *Pisaster brevispinus* | | 0.05 | *Megathura* | | 0.46 | *Megathura* | | 0.17 |
| | | | *Pisaster brevispinus* | | 0.20 | *Panulirus interruptus* | | 0.03 |
| | | | *Strongylocentrotus purpuratus* | | 0.05 | *Pisaster brevispinus* | | 0.03 |
| TURF COMMUNITY | | Abundance Estimate | TURF COMMUNITY | | Abundance Estimate | TURF COMMUNITY | | Abundance Estimate |
| Invertebrates | | | Invertebrates | | | Invertebrates | | |
| Cup coral (orange) | | occasional | Strawberry anemone | | common | Hydroid (total) | | common |
| Erect ectoprocts | | occasional | Cup coral (orange) | | occasional | Strawberry anemone | | common |
| Hydroids (other) | | occasional | Erect ectoprocts | | occasional | Barnacles (dead) | | occasional |
| Hydroids (total) | | occasional | Hydroid (ostrich plume) | | occasional | Encrusting sponges | | occasional |
| Abalone jingle | | rare | Hydroid (total) | | occasional | Erect ectoprocts | | occasional |
| | | | Hydroid (other) | | rare | Hydroid (ostrich plume) | | occasional |
| | | | | | | Hydroid (other) | | occasional |
| | | | | | | Cup coral (orange) | | rare |
| Algae | | | Algae | | | Algae | | |
| Filamentous reds | | abundant | Filamentous red | | abundant | Filamentous reds | | abundant |
| Foliose reds | | common | Foliose reds | | common | Foliose reds | | common |
| *Dictyota* | | occasional | | | | *Plocamiium* | | rare |
| Coralline reds | | rare | | | | | | |
| MACROALGAE | # per m² | Size Estimate | MACROALGAE | # per m² | Size Estimate | MACROALGAE | # per m² | Size Estimate |

Table 6

Abundance estimates for fishes are abundant =>50; common= 11-50; occasional = 2-11; and one = 1.

Size estimates: A=adult, J=juvenile, and Y=young of the year.

Abundance estimates for turf community are: abundant = >50% cover,common = 11-50% cover, occasional = 2-11% cover, and rare =<2% cover.